

HERE'S ONE OF THE MOST FASCINATING AND exciting electronic projects I've ever seen. A home-built electronic ping pong game that includes a special alternate version called "bumper" (illustrated on this month's cover). The game easily connects to most TV sets and uses the TV screen as the playing field. This particular game offers a challenge for just about every level of playing skill. Here are some of the features built into this special 2-game unit.

- Both vertical and horizontal paddle movement control.
- Controlled ball motion slam, spin or lob.
- Computer paddle control (one person can play against a machine that plays a perfect game or the machine can play against itself.
- Sound effects when the paddle hits the ball and when the ball rebounds off the game boundaries. Plus a special sound when a player scores a point.
- Randomized ball-speed ballangle integrator.
- Displayed boundries.
- Paddle size controls.
- On-screen scoring option.
- BUMPER—a second, built-in game.

How to play the game

The combination of vertical and horizontal paddle motion adds an extra dimension to the play. With it you can "rush the net" for a well-played power shot. Or you can chase after the ball to hit an overthe-head return. You can also try for a shot with lots of spin and angle. Or you can send a lob shot in and challenge your opponent to try and recover from that one.

The ball control built into the electronic is a unique randomizing integrator circuit

that controls both ball angle and speed. When you hit the ball, it can rebound at any one of ten different combinations of ball speed and ball angle; including straight across, either as a fast "smash" or a slow "lob".

The steeper rebound angles can make the ball bounce once, twice or even three times off the top and bottom boundries before your opponent can try and return the ball.

The built-in computer-control circuit provides automatic feedback to one (or both) paddles. This makes it possible for a single player to match his skills against the game. When this feature is switched on, the computer-controlled paddle automatically chases after the ball and bats it back to you . . . and it never misses.

This special feature also makes the game a cinch to demonstrate as it can be set to play a perfect game against itself.

The sound effects built into the unit add to the excitement and enhance the realism. Whenever the ball hits a paddle or boundary, you hear a "bonk"; and when some-

one misses a shot the game produces a "brrappt".

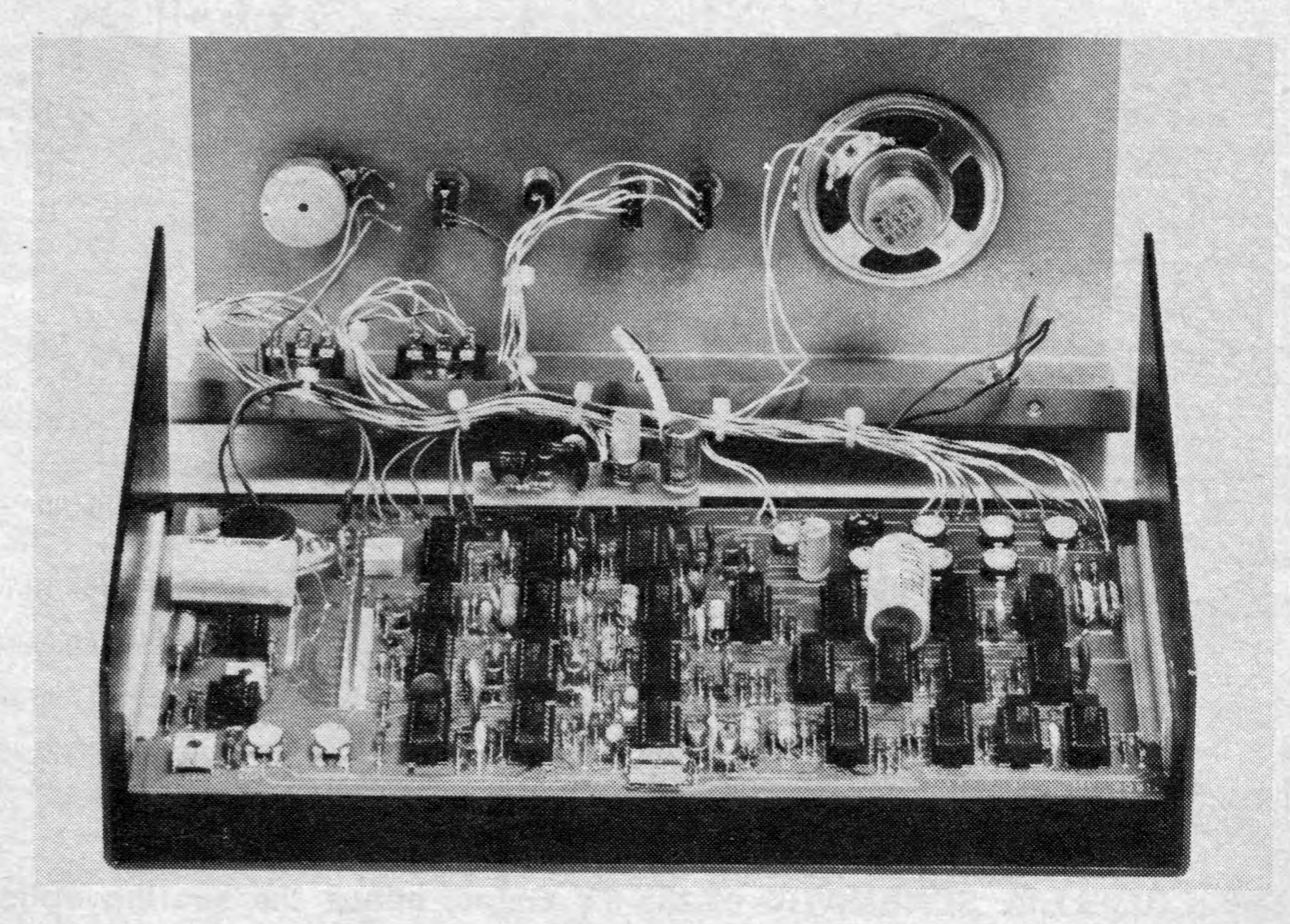
The ability to adjust the paddle size over a 3 to 1 range adds an adjustable skill level. The better you get as a player, the smaller you make the paddles; increasing the skill needed to play.

When you add on the digital scoring feature, you get a visible display on the TV screen. It is updated each time there is a score and the game ends automatically when either player reaches a score of 18. A reset button sets both players scores back at zero, and you're ready to start again.

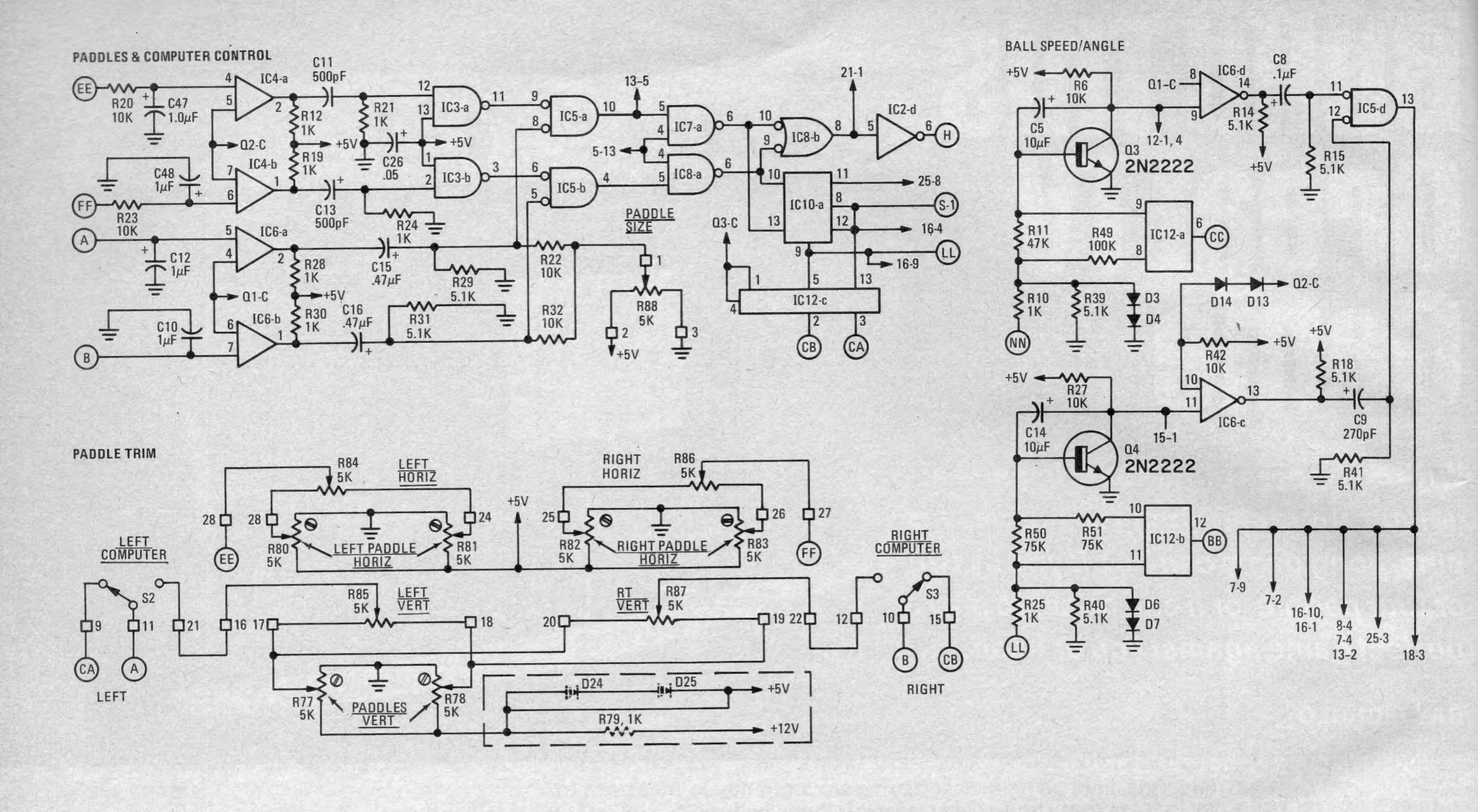
A second game

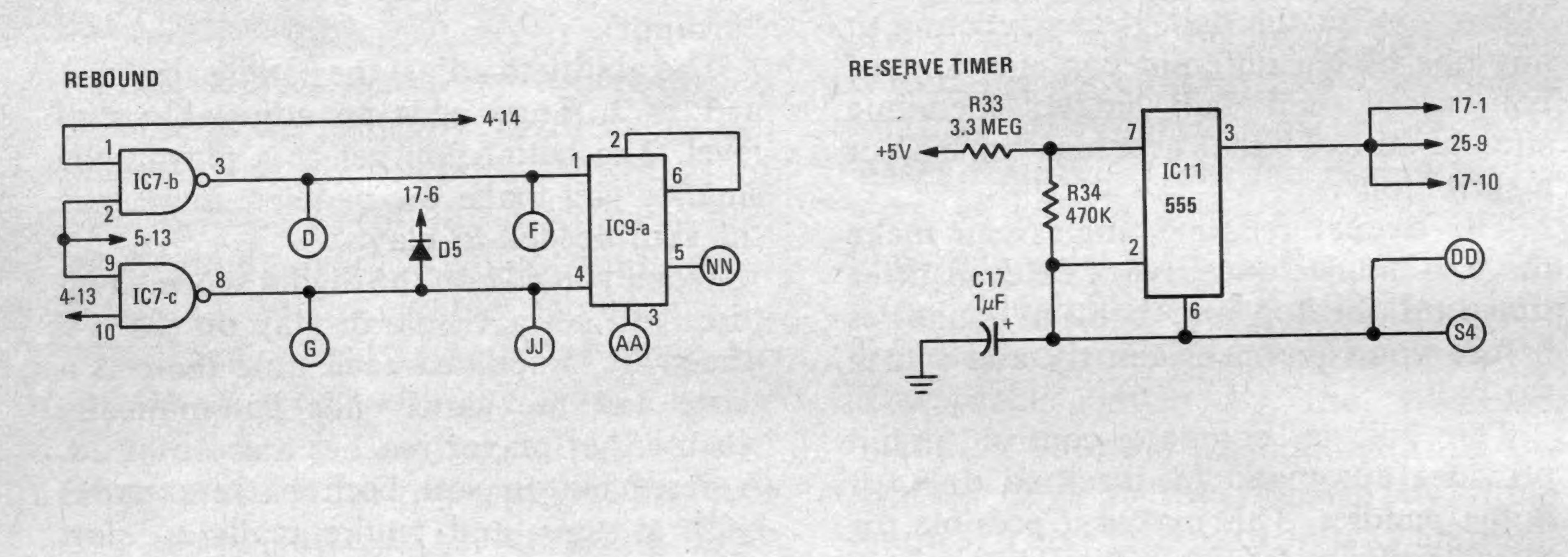
Bumper, as shown on this month's cover, adds a white "bumper" cube in the middle of the screen. This bumper adds two intriguing challenges to the game. When a player hits a ball that strikes the bumper on one of its vertical sides, the ball rebounds back to him at a random angle

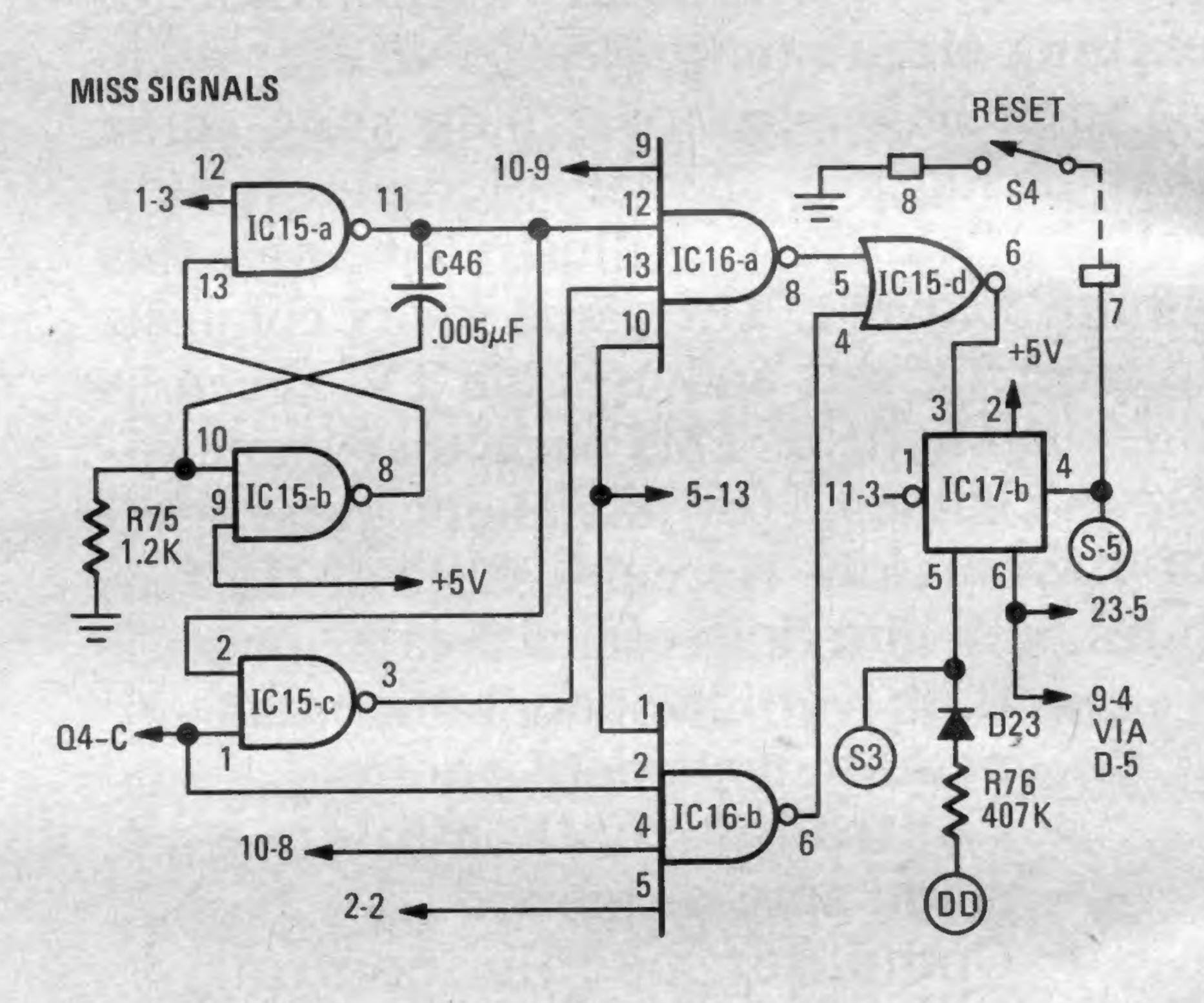
(Schematic on pages 36 & 37) (text continues on page 79)

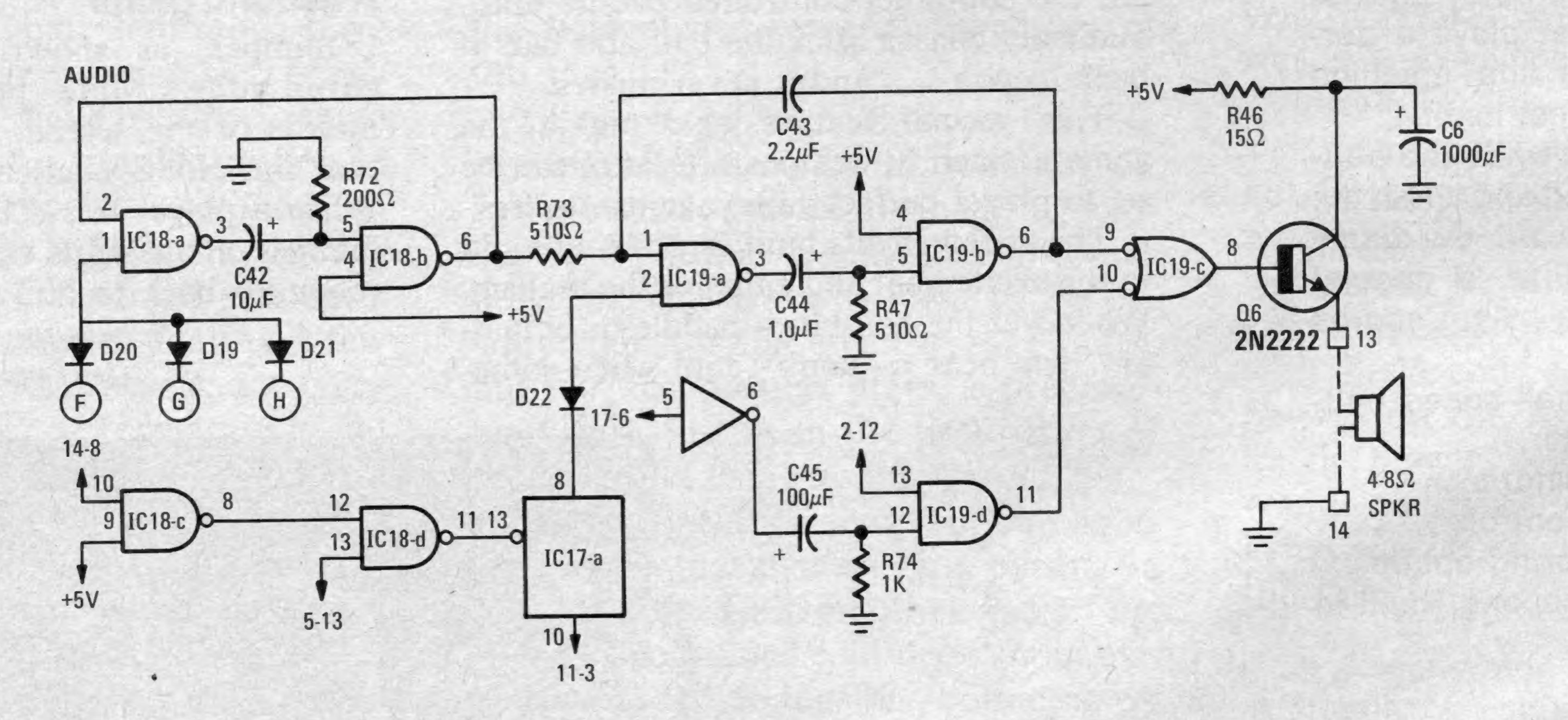


THE TV GAME is built on a single PC board. The optional scoring board (not shown) mounts on top of the main board.



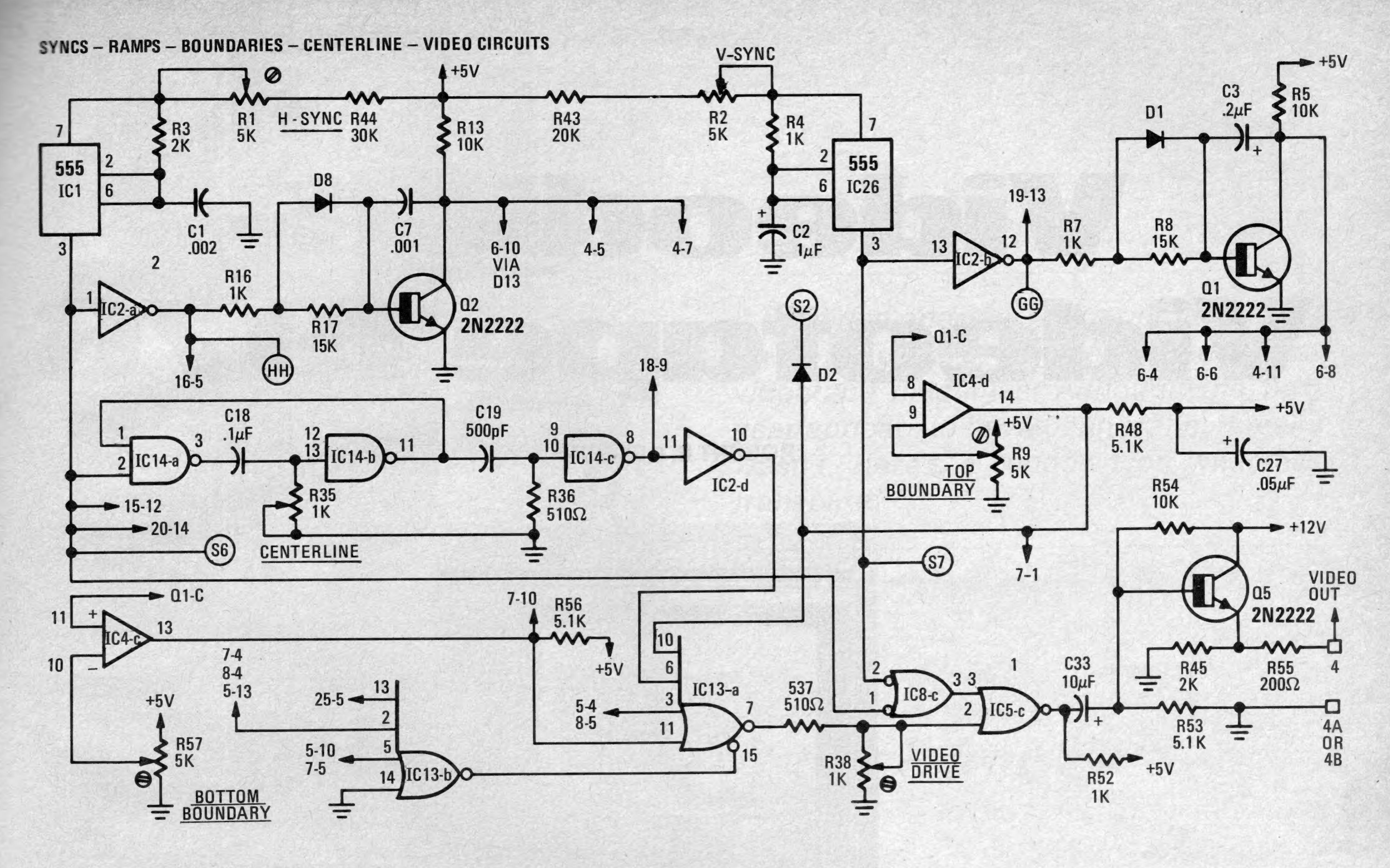


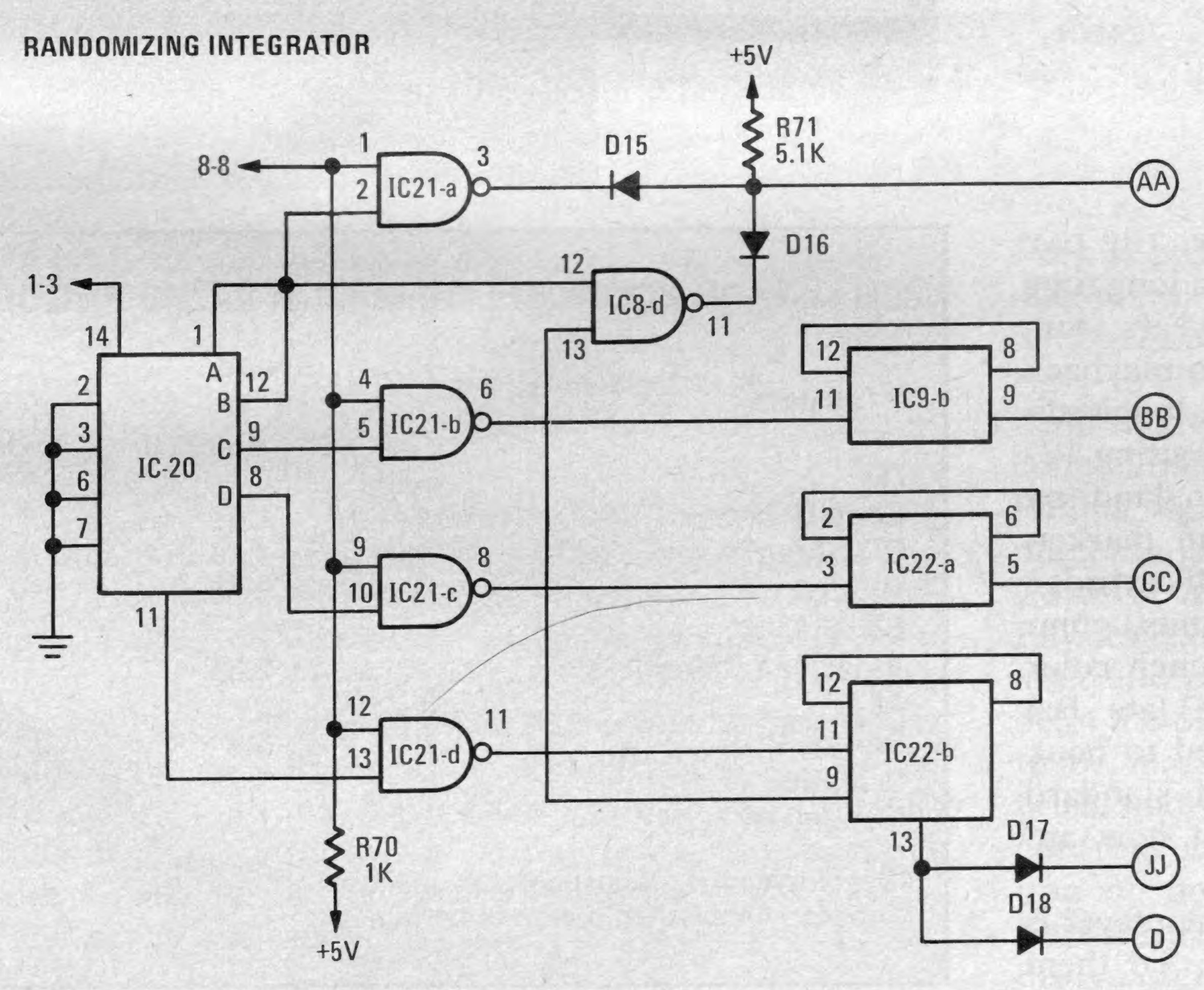


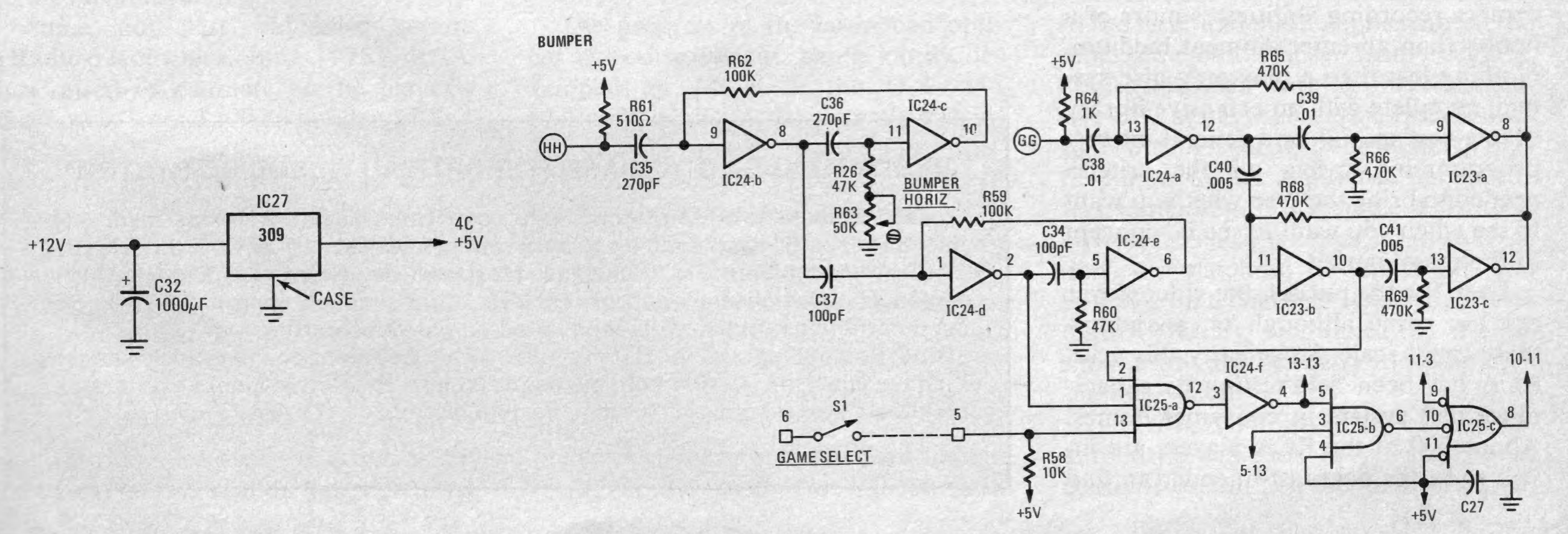


- NOTES:

 1. LETTERS WITHIN A CIRCLE INDICATE INTERCONNECTIONS BETWEEN TWO OR MORE SIMILARLY-MARKED POINTS. FOR EXAMPLE, AAAND AAAARE CONNECTED TOGETHER ON THE CIRCUIT BOARD.
- 2. POINTS MARKED BY TWO NUMBERS SEPARATED BY A DASH (AS 16-9) INDICATE AN IC NUMBER AND PIN NUMBER, RESPECTIVELY. THUS A LEAD MARKED 6-8 CONNECTS TO TERMINAL 8 ON IC6.
- 3. THE LETTER "S" FOLLOWED BY A NUMBER INDICATES A CONNECTION TO THE OPTIONAL SCORING BOARD.
- 4. NUMBERS NEXT TO SQUARES AS
 ARE CONNECTION TO OFF-BOARD COMPONENTS.
- 5. CAPACITORS C20-24 AND C26-31 BYPASS VARIOUS V_{CC} AND ARE NOT SHOWN ON THE SCHEMATICS.
- 6. IC1, IC11, IC26 555, IC2 7404, IC3, IC7, IC8, IC14, IC15, IC18, IC19 7400, IC4, IC6 339, IC5 7402, IC9, IC22 74C74, IC10, IC17 7474, IC12 4066, IC13 7423, IC16 7420, IC20 74C90, IC21 74C00, IC23, IC24 74C04, IC25 74C10, Q1 Q6 2N2222, D1 D8 1N4148, D9 D12 DELETED, D13 D25 1N4148 SEE PARTS LIST







(continued from page 35)

and speed. Then that player must hit the ball again or lose a point to his opponent.

The second challenge occurs whenever the ball touches the top or bottom of the bumper cube, Instead of rebounding, the ball enters the cube . . . and then after a brief random interval comes flying out. Both the path and speed of the ball are controlled by the randomizing integrator circuit. Also the ball may be angled from the bumper toward either player.

Look at the circuitry

The entire schematic for this game (with the execption of the scoring circuit) is shown on pages 36 and 37. The game provides a complete video image. It also generates the vertical and horizontal sync pulses necessary to provide a raster on the

IC1. The frequency of the vertical sync is determined by the combination of R2 and R43 and C2. Similarly, the horizontal sync frequency is determined by R1, R44 and C1. For long-term frequency stability both C1 and C2 are specially selected for their low temperature coefficients.

The outputs of both 555's are used to provide the required tuning signals within the game. Sync for the TV set is provided through IC8-c which is used as an OR gate to combine the vertical and horizontal sync pulses. IC8-c's output goes to the video combiner, IC5-c. This circuit will be discussed later. A vertical sync pulse defines the beginning of a TV frame, and a horizontal sync pulse defines the beginning of each line.

The vertical and horizontal sync signals are used to generate vertical and horizontal ramp signals. These are then used to provide position reference signals for

C11, C13, C19-500 pF or 470 pF

C17-1 µF, dipped tantalum

C25—not used

C50—not used

Transistors

1C2 - 7404

7400

IC5-7402

IC12-4066

1C13 - 7423

IC16-7420

IC20-74C90

IC21-74C00

IC25-74C10

S1-spst toggle

S2, S3—spdt toggle

Switches

IC23, IC24-74C04

IC27-LM309 (5v, 1A regulator)

IC4, IC6-339

IC9, IC22-74C74

IC10, IC17-7474

Q1 to Q6-2N2222

Integrated Circuits

IC1, IC11, IC26-555

Diodes

C34, C37-100 pF

C45-100 µF, radial

C49-6.8 μ F, tantalum

D9 to D12-not used

resistance joystick)

C40, C41, C46-.005 µF

C43-2.2 µF, dipped tantalum

C15, C16-0.47 µF, dipped tantalum

C20, C22, C23, C24, C38, C39-.01 µF

C21, C26, C27, C28, C29, C30, C31-.05

D1 to D8-1N4148 (or any signal diode)

D13 to D23-1N4148 (or any signal diode)

D24, D25-1N4148 (optional for low-

IC3, IC7, IC8, IC14, IC15, IC18, IC19-

PARTS LIST

All resistors 1/4-watt 5% unless noted

R1, R2, R9, R57, R77, R78, R80, R81, R82, R83-5000 ohms, trimpot

R3. R45-2000 ohms

R4, R7, R10, R12, R16, R19, R21, R24, R25, R28, R30, R52, R64, R70, R74-1000 ohms

R5, R6, R13, R20, R22, R23, R27, R32, R42, R54, R58-10,000 ohms

R8, R17-15,000 ohms

R11, R26, R60-47,000 ohms

R14, R15, R18, R29, R31, R39, R40, R41, R48, R53, R56, R71-5100 ohms,

R33-3.3 megohms

R34, R65, R66, R68, R69, R76-470,000 ohms

R35, R38-1000 ohms, trimpot

R36, R37, R47, R61, R73-510 ohms

R43-20,000 ohms nominal (V sync)

R44-30,000 ohms nominal (H sync)

R46-15 ohms

R49, R59, R62-100,000 ohms

R50, R51-75,000 ohms (or 68,000 or

82,000 ohms)

R55, R72-200 ohms

R63-50,000 ohms, trimpot (or 100,000 ohms, trimpot)

R67-Not used

R75-1200 ohms

R79-1000 ohms, optional, see text

R84, R85, R86, R87, R88-5000 ohms, potentiometer linear taper (or any value between 5000 and 25,000 ohms)

All capacitors 15 volts or more

C1-2000 pF, temp stab polystrene

C2-1.0 or 1.2 µF, temp stab tantalum

C3-0.2 µF, dipped tantalum

C4-not used

C5, C14, C33, C42-10 µF, axial

C6, C32-1000 µF, radial

 $C7 - .001 \mu F$

ing, and video.

C8, C18-0.1 µF, dipped tantalum

C9, C35, C36-270 pF

C10, C12, C44, C47, C48-1 µF, axial

TV screen. You should think of this game

as having eight separate functional areas.

These are the vertical and horizontal sync,

paddle circuits, playing field circuits, ball

circuits, hit-and-miss circuits, audio, scor-

are generated by two 555 IC times (IC26

and IC1). The vertical sync frequency is

generated by IC26, the horizontal sync by

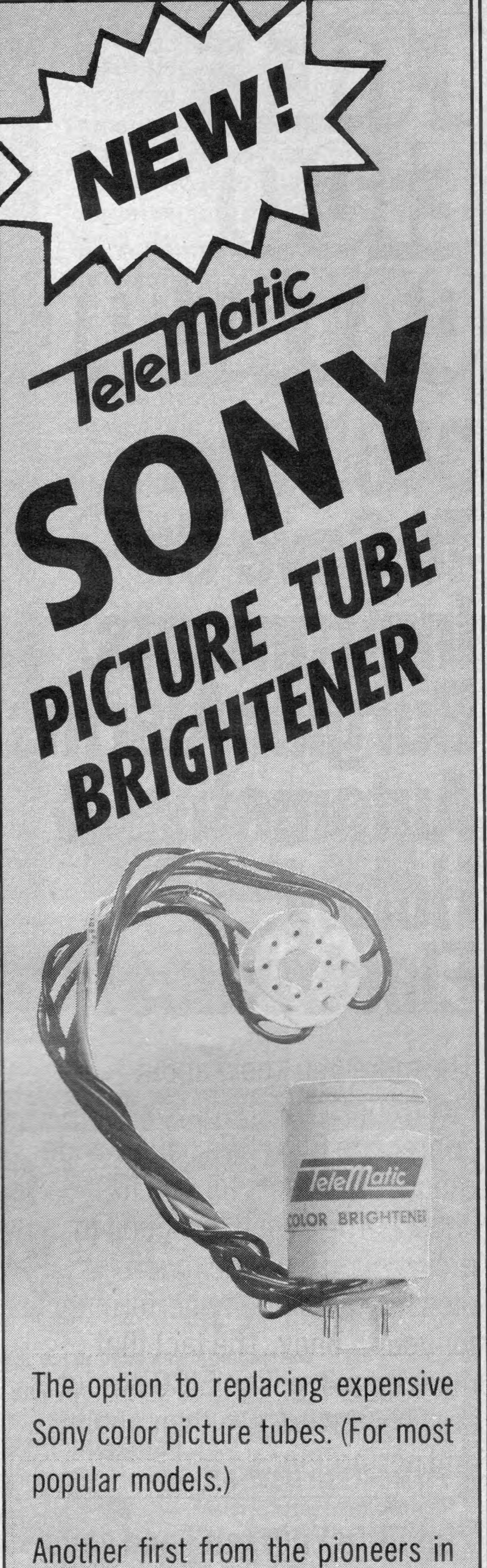
The vertical and horizontal sync pulses

S4-spst N.O. momentary push button

SPKR-4 to 8 ohms, 21/4 inch diameter

At the beginning of a frame, Q1 is momentarily turned on by the inverted vertical sync pulse, bringing the vertical ramp (continued on page 80)

the paddles, ball and both boundaries. The vertical ramp is generated by transistor Q1 and its associated components. The vertical sync pulses from IC26 are inverted by IC2-b and fed via R7 and R8 to the base of transistor Q1.



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signal to 0 volts. The ramp voltage then rises as Q1 is switched off and capacitor C3 charges through R5, R8 and R7. The output of IC26 is at ground during this period.

The horizontal ramp circuit operates in a similar manner with a separate but rather identical circuit. Thus for each TV frame, the vertical ramp makes one complete cycle and, for each TV scan line, the horizontal ramp makes one complete cycle.

The following items are available from Visulex, P.O. Box 4204, Mountain View, CA 94040

Main circuit board, with pre-aligned horizontal and vertical sync oscillators soldered in place. Includes circuitry (but not components) for ball, paddle and boundary display, sound effects, computer-control module, paddle size selector, ball speed/angle randomizer, game action electronics for bumper and power filters. Order Kit MB-3: \$29.50

Component kit for main board. Contains all additional ICs, IC sockets, transistors, resistors, diodes, trimpots and 5V regulator Order kit MBK-3: \$48.50

Assembled and tested main board. Order MBA-3: \$105.00

On screen scoring circuit board, including LSI character display generator IC. Order kit SB-3: \$18.75

Component kit for scoring board contains all additional ICs, IC sockets, resistors, capacitors, diodes and trimpots. Order kit SBK-3: \$20.50

Assembled and tested scoring board. Order SBA-3: \$55.00

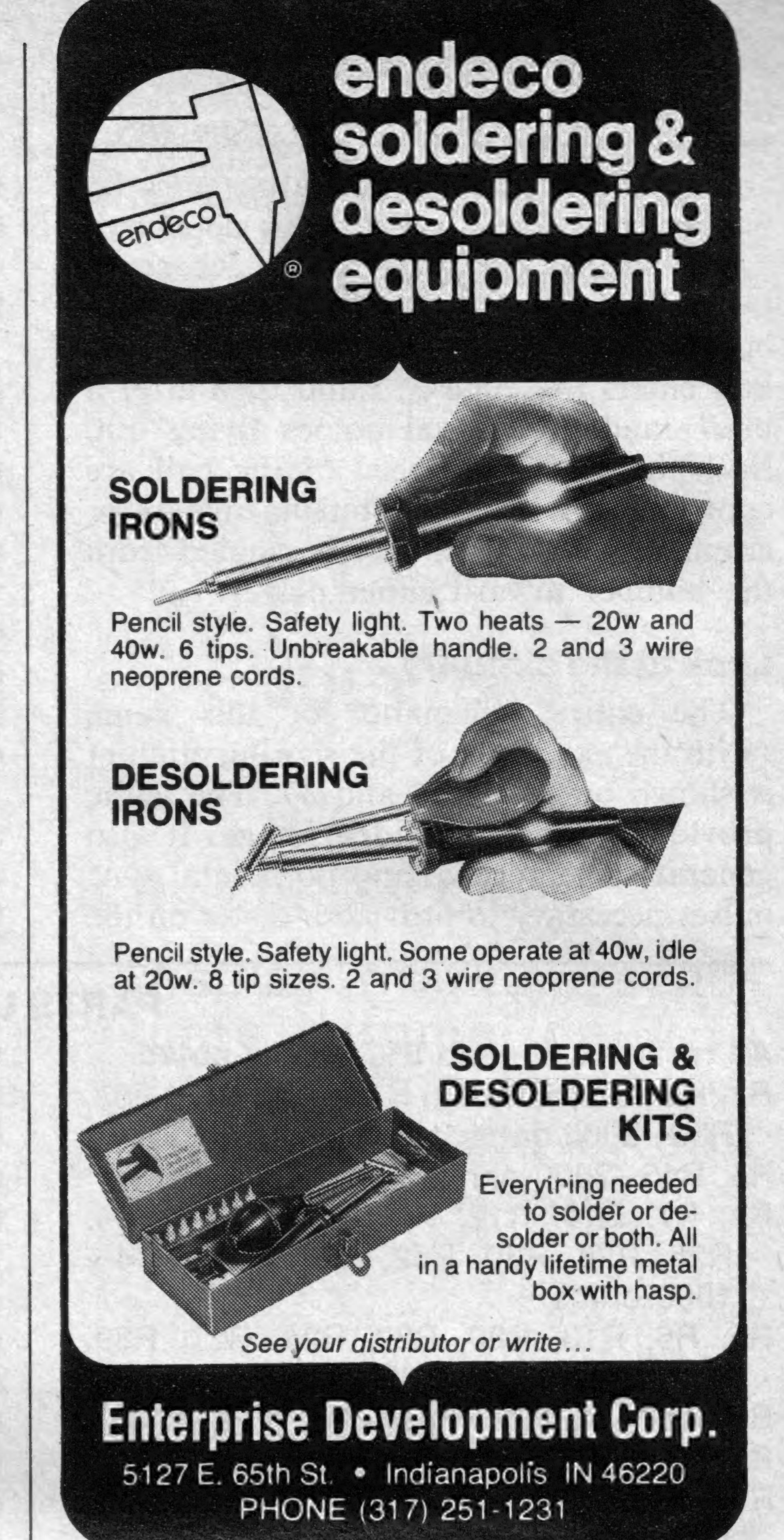
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Power supply, 12 volts DC. Powers the entire game including scoring module. Order kit PS-3; \$8.70

Cases. Including main cabinet plus remote player control boxes. Order kit CC-3: \$22.50

The Everything Package. Supplies everything needed. Includes CP-3, MB-3, MBK-3, SB-3 SBK-3 AK-3, PS-3 and CC-3. Order EP-3: \$162.50

The playing field is comprised of the top and bottom boundaries and the centerline. The centerline is generated by three sections of IC14 (a, b and c), C18, C19, and R36. Control R35 sets the position of the



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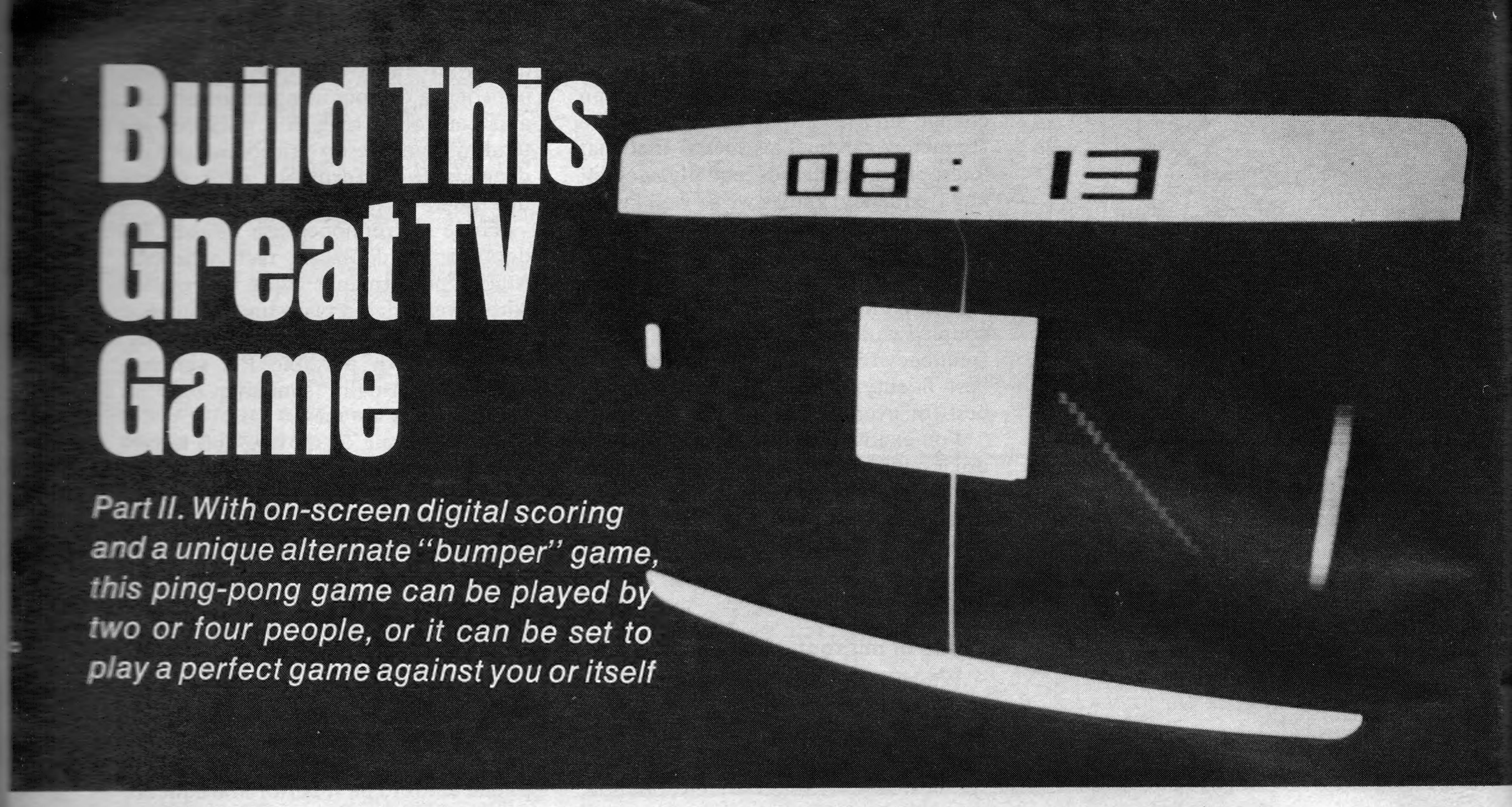
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Circle 65 on reader service card



THE FIRST PART OF THIS ARTICLE (JUNE, 1976) presented the schematic and began the discussion of how the circuit works.

This second part of the article concludes the discussion of the main circuit board and presents the foil patterns.

Generating the ball

In a manner somewhat similar to that used to produce the paddles, we generate the ball. Two comparators are used to determine the vertical and horizontal coordinates of the ball. The actual position of the ball is set by the voltages appearing on the collectors of transistors Q3 and Q4.

Q3 determines the vertical position and Q4 the horizontal position. When the horizontal ramp voltage reaches the voltage of Q3, pin 14 of IC6-d goes low, producing a negative pulse at pin 11 of IC5-d. These two pulses are AND'ed by IC5-d to produce a positive pulse at the output pin 13 of IC5-d. This signal is the ball signal that is displayed on the screen via IC13.

Since the ball is always in motion, it is apparent that the voltages on Q3 and Q4 are constantly changing. The direction (positive or negative) of that change is determined by the state of two flip-flops, IC9-a and IC10-a. The signal at pin 5 of IC9-a determines the balls vertical direction. The signal at pin 9 of IC10-a determines its horizontal direction. The rate of change (ball speed) is determined by the rate at which the two capacitors C5 (vertical) and C14 (horizontal) are charging or discharging.

Let us assume for the purpose of this description that the ball on the screen is moving diagonally from the upper left to the lower right corner. When this is happening the voltage on the collectors of Q3 and Q4 are both increasing in the positive direction and flip-flops IC9-a and IC10-a are both in the set state.

Now the ball reaches the bottom bound-

ary, and must rebound back into the playing field. The ball is made to rebound simply by changing its vertical direction; since IC9-a controls ball vertical direction, all that is required is to reset IC9-a. This resetting is done by the signal from pin 8 of IC7-c. The inputs of this gate are the signals from pin 9 of IC7-c and pin 10 of IC7-c. The ball signal is on pin 9 of IC7-c and the bottom boundaries on pin 10 of IC7-c.

If the ball and bottom boundary both occur at the same time (the ball has reached the boundary), both of these inputs will be high, causing their ANDed output to go low. This output signal goes to the direct clear input of IC9-a causing the flip-flop to reset, which in turn reverses the direction of the charge on C5 and Q3, thereby reversing the vertical direction of the ball.

The top boundary rebound functions in a similar manner. The ball is ANDED with the top boundary signal at pin 3 of IC7-b. When a coincidence occurs at the top boundary, IC9-a is set, causing the ball to reverse direction downwards. (Diode D2 connected to pin 14 of IC4-d and pin 1 of IC7-b is part of the video circuit and allows the score to be displayed in the top boundary area and has no function in the rebound circuit.

Horizontal direction of the ball is controlled by IC10-a and Q4/C14 in a similar manner. Horizontal direction is reversed only in an instance where the ball strikes a paddle (or the bumper). Horizontal direction is reversed by resetting IC10-a. This is controlled by the output at pin 6 of IC7-a and pin 6 of IC8-a, which are ANDed outputs of the ball and right paddle and left paddle, respectively.

They are used to direct set or direct clear IC10-a in the same manner as IC9-a is controlled for vertical direction. Additionally, the output from pin 8 of IC8-b is

the oned signal from either paddle which indicates a paddle hit. The signal is used for the audio as well as in the ball angle randomizer circuit.

When the ball is hit

When the ball rebounds from a paddle, several other things take place. The ball may or may not change speed or angle. Whether or not it does is determined in the ball-hit randomizer circuit. This circuit is a pseudo-random pattern generator that gives ten different combinations to determine the ball's speed and angle. The ten combinations are provided by IC20, a counter, that is clocked at the horizontal sync rate (15, 750 Hz). Thus, the four outputs (A, B, C, D) are changing at rates of 7875, 3937, 1968 and 984 times per second.

When a paddle-hit occurs, the four sections of IC21 are enabled by the paddle-hit signal, and at that instant the pattern contained in IC20 is applied to the clock inputs of four flip-flops [IC9 (a and b) and IC22 (a and b)].

If the respective output of the pattern happens to be low at the time of the hit, the corresponding flip-flops will toggle. As a result pin 5 of IC9-a, which controls vertical direction, may reverse if the signal at pin 12 of IC20 happened to be low at the time of the hit, and so on for pin 5 of IC22-a and pin 9 of IC22-b.

The signal from pin 5 of IC22-a controls vertical speed. The signal from pin 9 of IC22-b is used to allow a nearly horizontal shot. When set, it causes the signal at pin 11 of IC8-d to continuously toggle IC9 at a 7875 Hz rate. Thus the ball will travel nearly horizontally because the signal at pin 5 of IC9-a will be rapidly setting and resetting during the ball's travel across the screen, preventing capacitor C14 from either charging or discharging and the ball from changing its vertical direction.

PARTS LIST

All resistors 1/4-watt 5% unless noted R1, R2, R9, R57, R77, R78, R80, R81, R82, R83-5000 ohms, trimpot R3, R45-2000 ohms R4, R7, R10, R12, R16, R19, R21, R24, R25, R28, R30, R52, R64, R70, R74-1000 ohms R5, R6, R13, R20, R22, R23, R27, R32, R42, R54, R58-10,000 ohms R8, R17-15,000 ohms R11, R26, R60-47,000 ohms R14, R15, R18, R29, R31, R39, R40, R41, R48, R53, R56, R71-5100 ohms, R33-3.3 megohms R34, R65, R66, R68, R69, R76-470,000 ohms R35, R38-1000 ohms, trimpot R36, R37, R47, R61, R73-510 ohms R43-20,000 ohms nominal (V sync) R44-30,000 ohms nominal (H sync) R46-15 ohms R49, R59, R62-100,000 ohms R50, R51-75,000 ohms (or 68,000 or 82,000 ohms) R55, R72-200 ohms R63-50,000 ohms, trimpot (or 100,000 ohms, trimpot) R67-Not used R75-1200 ohms-R79-1000 ohms, optional, see text R84, R85, R86, R87, R88-5000 ohms, potentiometer linear taper (or any value between 5000 and 25,000 ohms) All capacitors 15 volts or more C1-2000 pF, temp stab polystrene C2-1.0 or $1.2 \mu F$, temp stab tantalum C3-0.2 µF, dipped tantalum C4-not used C5, C14, C33, C42-10 µF, axial C6, C32-1000 µF, radial $C7 - .001 \mu F$ C8, C18-0.1 µF, dipped tantalum

C11, C13, C19-500 pF or 470 pF C15, C16-0.47 µF, dipped tantalum C17-1 µF, dipped tantalum C20, C22, C23, C24, C38, C39-.01 µF C21, C26, C27, C28, C29, C30, C31-.05 C25—not used C34, C37-100 pF C40, C41, C46-.005 µF C43-2.2 µF, dipped tantalum C45-100 μ F, radial C49-6.8 μ F, tantalum C50-not used Diodes D1 to D8-1N4148 (or any signal diode)

D9 to D12-not used D13 to D23-1N4148 (or any signal diode) D24. D25-1N4148 (optional for lowresistance joystick)

Transistors

Q1 to Q6-2N2222

Integrated Circuits

IC1, IC11, IC26-555

IC2-7404

1C3, IC7, IC8, IC14, IC15, IC18, IC19-7400

IC4, IC6-339

IC5-7402

IC9, IC22-74C74

IC10, IC17-7474

IC12-4066

IC13-7423

IC16-7420

1C20-74C90

IC21-74C00

IC23, IC24-74C04

IC25-74C10

IC27-LM309 (5v, 1A regulator)

Switches

S1—spst toggle

S2, S3-spdt toggle

S4-spst N.O. momentary push button SPKR-4 to 8 ohms, 21/4 inch diameter

The following items are available from Visulex, P.O. Box 4204, Mountain View, CA 94040. Also available from Technology Trends, P.O. Box 732, Manhasset, NY 11030

C10, C12, C44, C47, C48-1 µF, axial

C9, C35, C36-270 pF

Main circuit board, with pre-aligned horizontal and vertical sync oscillators soldered in place. Includes circuitry (but not components) for ball, paddle and boundary display, sound effects, computercontrol module, paddle size selector, ball speed/angle randomizer, game action electronics for bumper and power filters. Order Kit MB-3: \$29.50

Component kit for main board. Contains all additional ICs, IC sockets, transistors, resistors, diodes, trimpots and 5V regulator Order kit MBK-3: \$48.50

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Ball speed

Should the ball encounter either the top or bottom boundary in this mode, the signal at pin 9 of IC22-b will be cleared through diodes D17 or D18 and the ball will rebound off the boundary. The two diodes, D15 and D16 that connect to pin 3 of IC21-a and pin 11 of IC8-d are simply an or gate to allow either gate to clock pin 3 of IC9-a.

Ball speed is controlled in both the vertical and horizontal directions. As was previously mentioned, the signal from pin 9 of IC9-b controls the horizontal speed while the signal at pin 5 of IC22-a controls the vertical speed. The element that determines the speed is IC12, a bilateral switch.

You will recall from the previous discussion that ball speed is a function of the charge rates of capacitors C5 and C14. These rates are determined by resistors R11 and R50. The values of these components were selected to produce the slower ball speeds. When the faster ball speed has been selected, an additional resistance R49 (or R51) is switched across the appropriate resistor by IC12, under the control of the signal from pin 9 of IC9 or pin 5 of IC22. This additional resistance effectively lowers the value of R11 (or R50) thereby increasing the ball's speed.

The computer-controlled paddles, a special feature of this machine and not to our knowledge seen elsewhere operates via IC12 too. By means of the external SPDT switches, the vertical paddle position voltage on pin 4 of IC4 and pin 6 of IC4 can be determined by either the player potentiometer or the computer control circuitry.

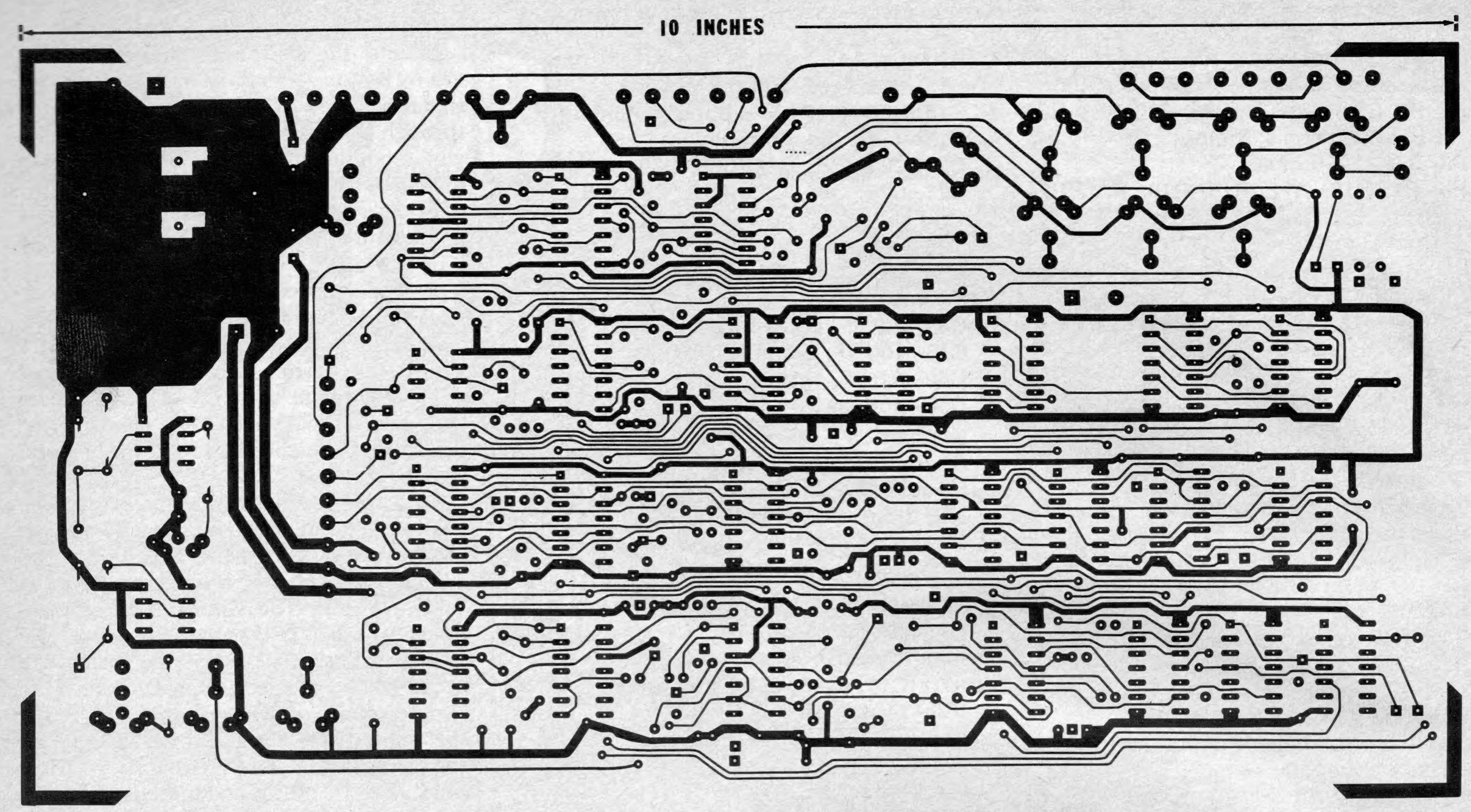
Recall the previous discussion of how the vertical position of the ball is determined by the voltage appearing on the collector of Q3. If this same voltage were applied to the paddle vertical position input, then the paddle should have the same vertical position as the ball. This is exactly the case. Instead of the player potentiometer determining the vertical position of the paddle, then, a paddle is slaved to the ball. Thus, the paddle tracks the ball motion and always has the same vertical position as the ball.

Since there are two paddles, it is necessary to select which one is to be slaved to the ball. This selection is done via the remaining two sections of IC12 and is controlled by IC10. When the ball is travelling toward the left side, the left hand paddle is slaved to the ball. When IC10 caused the ball to reverse direction, the other paddle becomes selected at that time.

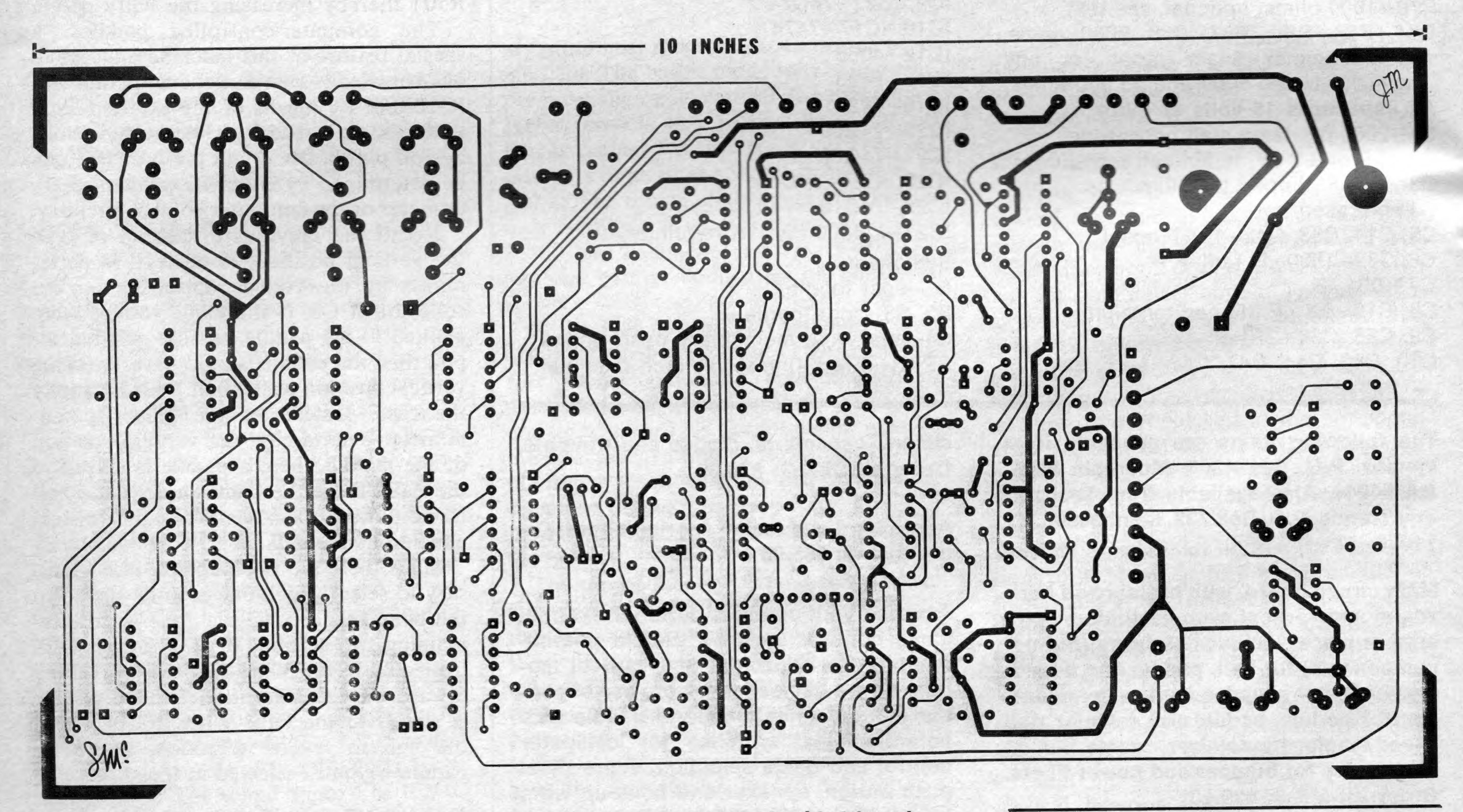
Registering a point

A miss is detected by two end boundaries which are generated by IC15 and IC16, although not displayed on the screen. The left-hand boundary is generated by stretching the width of the horizontal sync pulse to about 8 microseconds through pins 11 and 8 of IC15; and then by and'ing with the ball signal from pin 13 of IC5, the left-hand signal from pin 9 of IC10, and the inverted ball horizontal position signal from Q4 (also pin 11 of IC6) via pin 3 of IC15.

Coincidence of all four input signals on IC16 (ball presence, ball on left, ball going left, very near edge of screen) constitutes



MAIN CIRCUIT BOARD FOIL PATTERN shown from component side of double-sided board.



MAIN CIRCUIT BOARD FOIL PATTERN shown from bottom side of double-sided board.

a miss. The output pin 8 of IC16 goes low, through IC15 which is used as an or gate and sets pin 5 of IC17, which indicates a miss. Similarly, a right hand miss is detected by pin 6 of IC16, which detects ball off the screen to the right at the beginning of the next scan line.

With pin 5 of IC17 set, pin 5 is high, which allows capacitor C17 to start charging. When C17 reaches the required level, IC11, the re-serve timer generates a reserve signal. The signal resets pin 5 of IC17 and also clocks pin 9 of IC10 causing the ball to reverse direction horizontally.

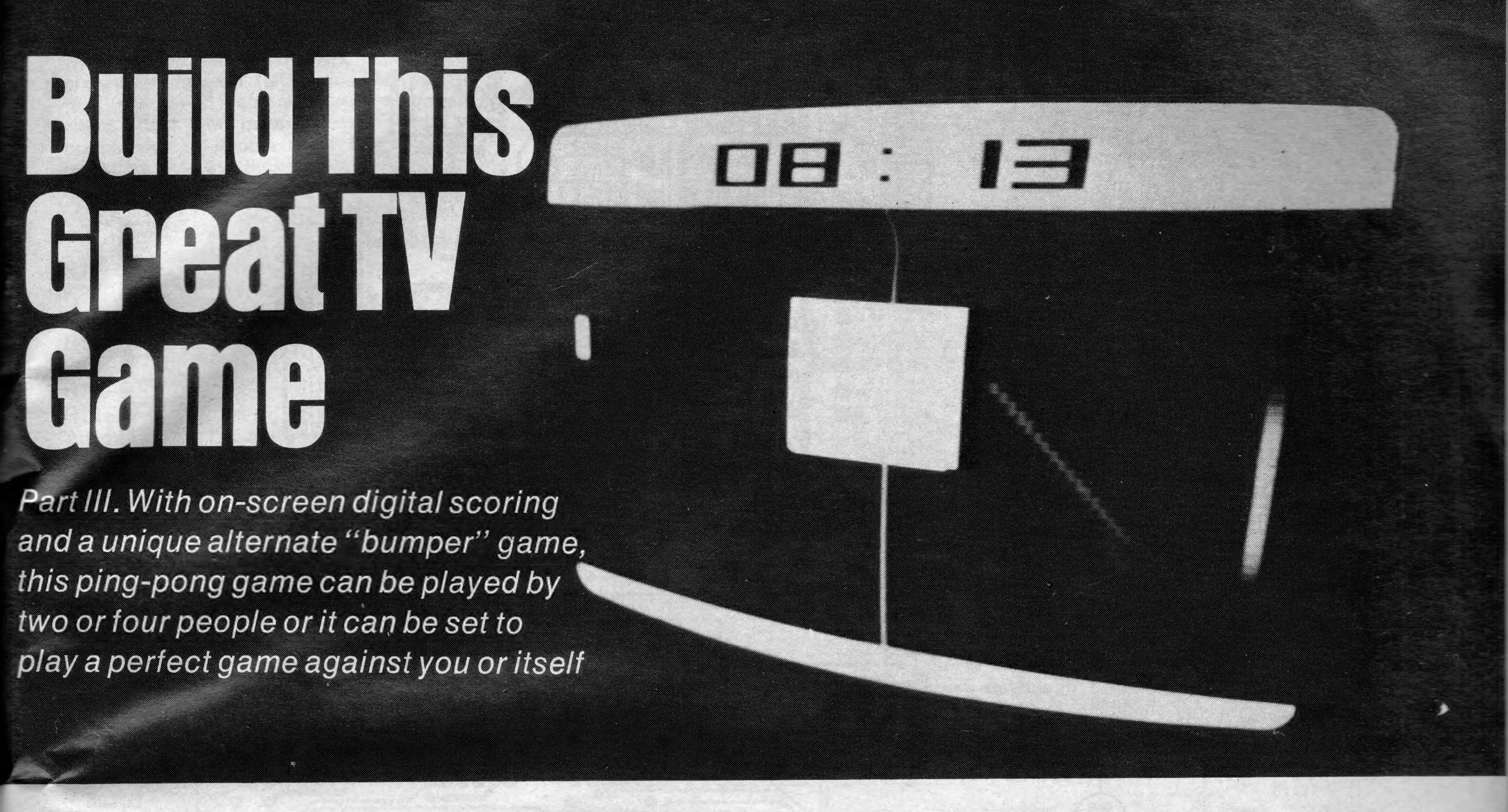
In addition, with the occurrence of a miss signal pin 5 of IC9 is cleared from pin 6 of IC17, which causes the ball to return to the top of the screen. You will note that the ball always re-serves from either the upper right or upper left corner.

In the August issue we will present the description of the second game "Bumper" and the remaining construction information, which will include the parts location diagram. This article has required more space than we originally expected, but we want to present all the information we have.

R-E



"Rampart, this is three. I have a mahogany patient, about four years old, picture weak, stand by for vital signs."



at the circuitry for Bumper and examine the methods for connecting the game to a TV set. In addition, we will describe a trouble-shooting system to use if you can't get your game to work.

Bumper is generated by four one-shots. Two of them determine the bumper's position. The other two determine its dimensions. The vertical position is set by the signal from pin 12 of IC24 and pin 8 of IC23. The vertical dimension is set by the signals from pins 8 and 12 of IC23. The horizontal position is determined by the signals from pins 8 and 10 of IC24. The horizontal dimension is determined by the signals from pins 2 and 6 of IC24. These one-shots work similarly to the one-shots used to generate the center line and top boundaries (see Radio-Electronics, July 1976). The output of the bumper comes from pin 12 of IC25 and it AND's the vertical and horizontal dimensions to produce the rectangle.

A third input is used to enable or disable this game with the GAME SELECT switch. The output is inverted and displayed on the screen. And also AND'ed with the ball signal from pin 13 of IC5. This output is used to clock IC10, the horizontal position flip flop. When the ball enters the bumper, IC10 is clocked. This causes the ball to reverse horizontal direction. However, because of the size and shape of the bumper, and the various entry angles, the ball will not always immediately leave the bumper. Thus, on successive lines, the ball may still be in the bumper. When this happens IC10 will continue to be clocked and the ball will continually reverse direction until it is finally clear of the bumper. Since the length of time the ball remains in the bumper is random, the direction of the emerging ball is unpredictable. The signal from pin 8 of IC 25 is used as an OR gate to combine the hit signals with the signal from the reserve timer.

Audio for both games is generated by IC18, IC19 and IC6. When a ball is hit with a paddle, or when a ball strikes a boundary, a one-shot made of two sections of IC18 is triggered. The diodes D19, D20 and D21 are an OR gate. And the signals from pins 3 and 6 of IC19 comprise a free-running oscillator operating at about 1kHz. Thus, a series of pulses are generated at pin 6 of IC19 for the period of the one-shot. This pulse string is amplified by Q6 and is the "bink" heard on a hit or rebound.

The "brapp" missound is generated by ANDing the vertical sync pulses with a longer pulse generated by the flip flop, pin 6 of IC17. Capacitor C45 determines the length of the "brapp." When IC17 sets, the Q output is inverted via IC23 and differentiated by capacitor C45 and resister R74. On a re-serve, the ball crosses through the top boundary and could cause a false "brapp" signal. This is prevented by pin 8 of IC17 which is set on a re-serve and cleared the first time the ball crosses the center line. With pin 8 of IC17 set, pin 3 of IC19 is disabled.

IC13 is used to combine all of the video outputs from the boundaries-paddles, ball, center line, and bumper—into one video signal to be displayed on the TV screen. The scoring video output is OR'ed for the top boundary video through diode D2 to produce black numerals on the white top boundary field. The output goes through a voltage divider R37-R38 which is used to adjust for the correct video level. The resulting video signal is then OR'ed with the combined vertical and horizontal sync from pin 3 of IC8, in IC5. The resulting video signal is buffered by an emitter-follower circuit, transistor Q5, and is available for direct connection to a video display unit via the video detector.

Connecting to the TV set

Connecting external devices delivering

an RF signal to the antenna terminals of a television set is prohibited by FCC rules. Therefore, the only acceptable method is to feed the signal from our TV game directly into the set's video detector/amplifier. To do this, there are two preliminary steps that must be taken. First, you must be sure that the TV set you intend to use has a power transformer and is not an AC/DC set that has one side of the power line connected to the chassis. Sets such as these offer a potentially dangerous shock hazard, and must not be used with the circuits recommended here. Before proceeding further, be sure that the set you plan to modify is safe to use for the game and that the chassis is isolated from the power supply. Next, you must secure a complete set of schematics of the set, either directly from the manufacturer or from a Howard Sams' Photofact. This schematic is a necessary part of hooking up our game to your TV.

The point for direct connection is shown in Fig. 1. Locate this point in the schematic for your TV set and then find that point physically in the TV set where the input signal first enters the first video amplifier.

If your set is a vacuum tube type, look at Fig. 2. The modification here consists of three simple sections—a self-biasing cathode circuit, an input jack with bypass resister, and a game/video selector switch. The cathode bias circuit provides about 2 volts (positive) on the cathode for game playing. (And the switch re-establishes the typical 0 cathode voltage for TV watching). For both tube and transistor type sets, the sync level runs about 2 volts below the white level. Any existing bias network on the cathode must be increased to bias the black level (vs. white) for game playing.

If the TV set is a transistor type, use any of the circuits shown in Fig. 3. These will provide the necessary white level/

black level biasing through which the diode drops within the transistors (and in a separate diode for case 3). When no video signal appears, the video driver is driven below the black level to about 1.2 volts. When a white signal of 2 volts appears, the video driver is biased to its usual 3+volts. The ideal direct video connection circuit will provide the same level of white level bias and black level bias for game playing as for TV watching.

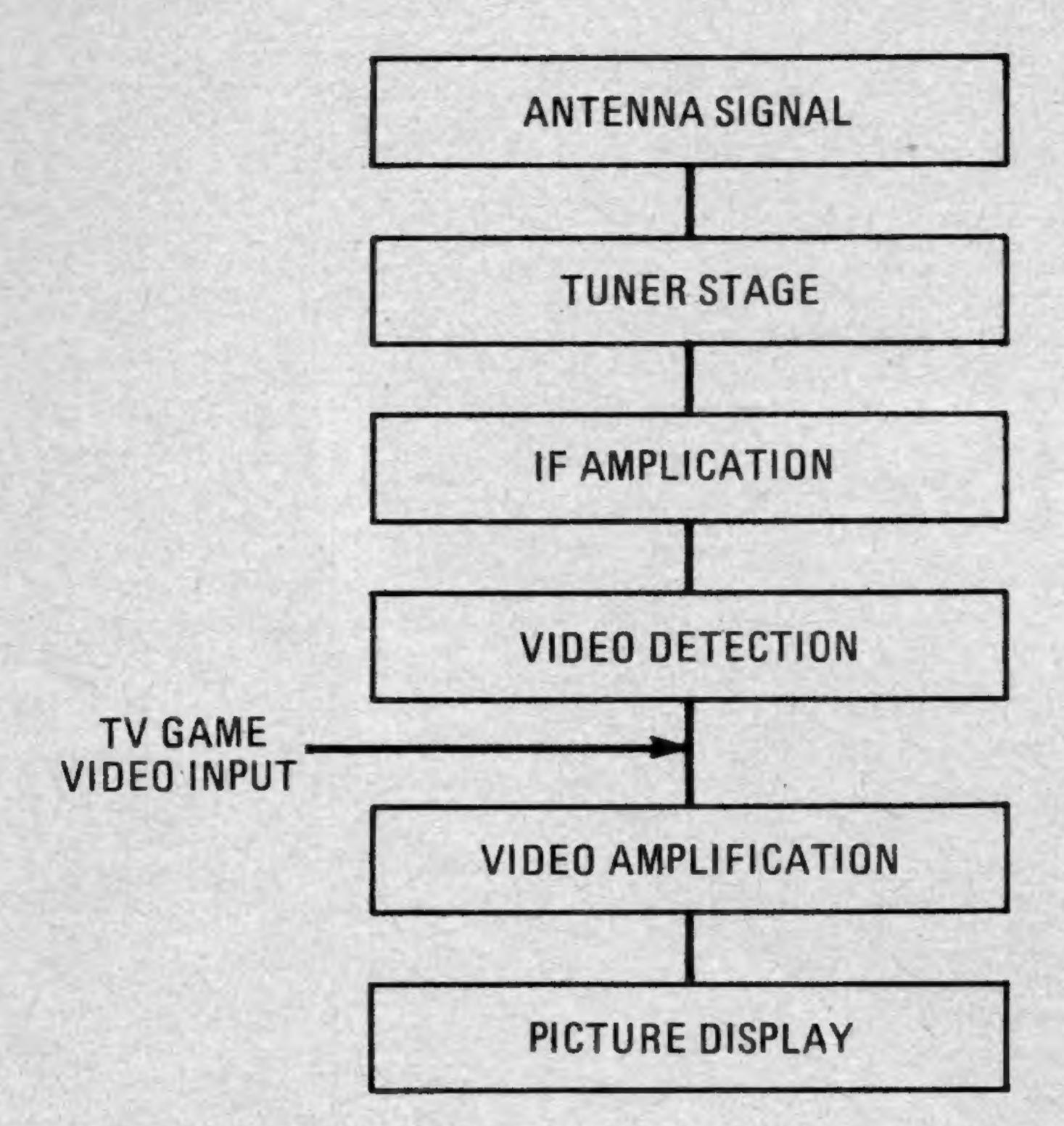


FIG. 1—TV GAME is connected directly to input of video amplifier stage.

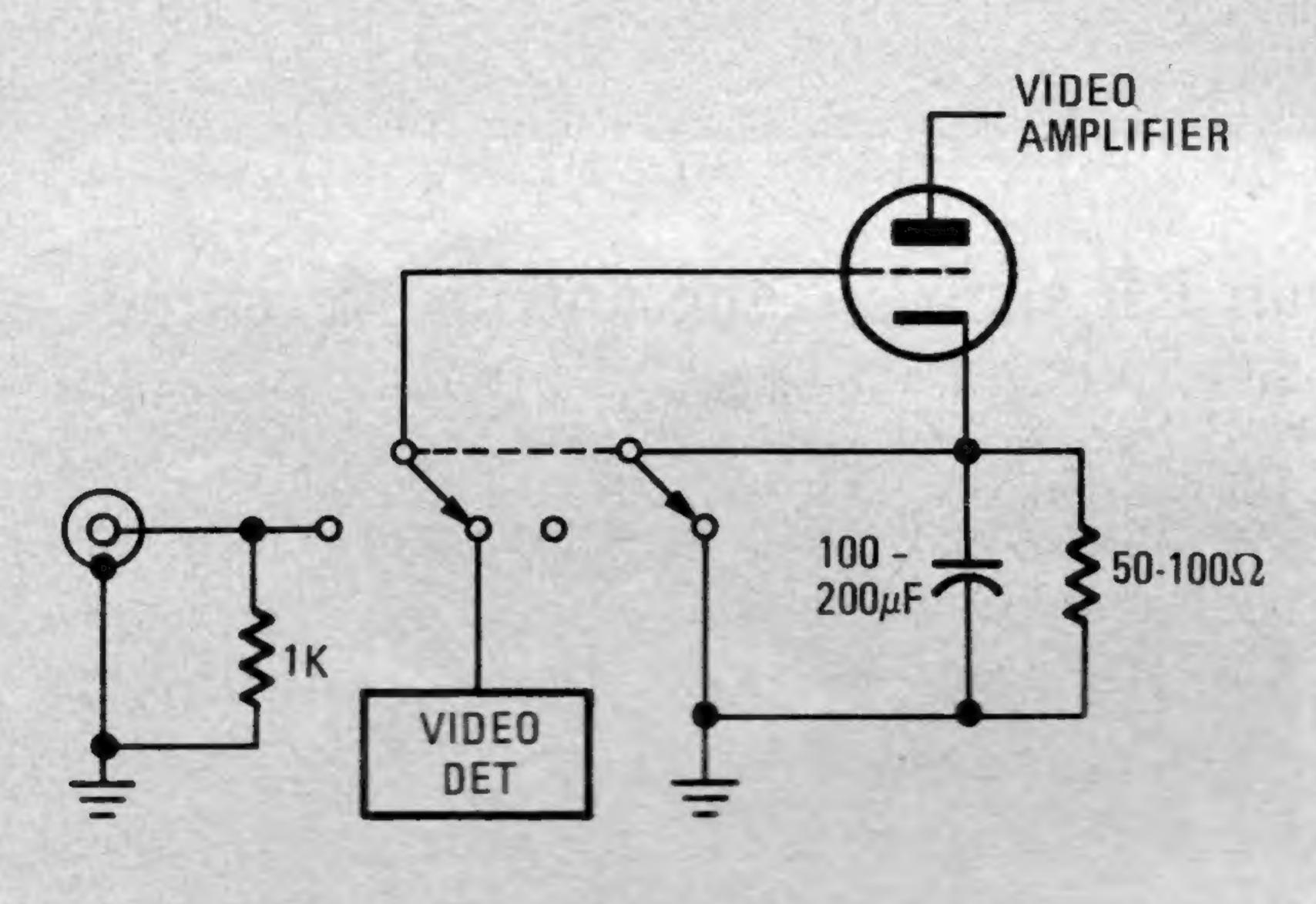


FIG. 2—TUBE-TYPE TV requires minor modification to connect TV Game.

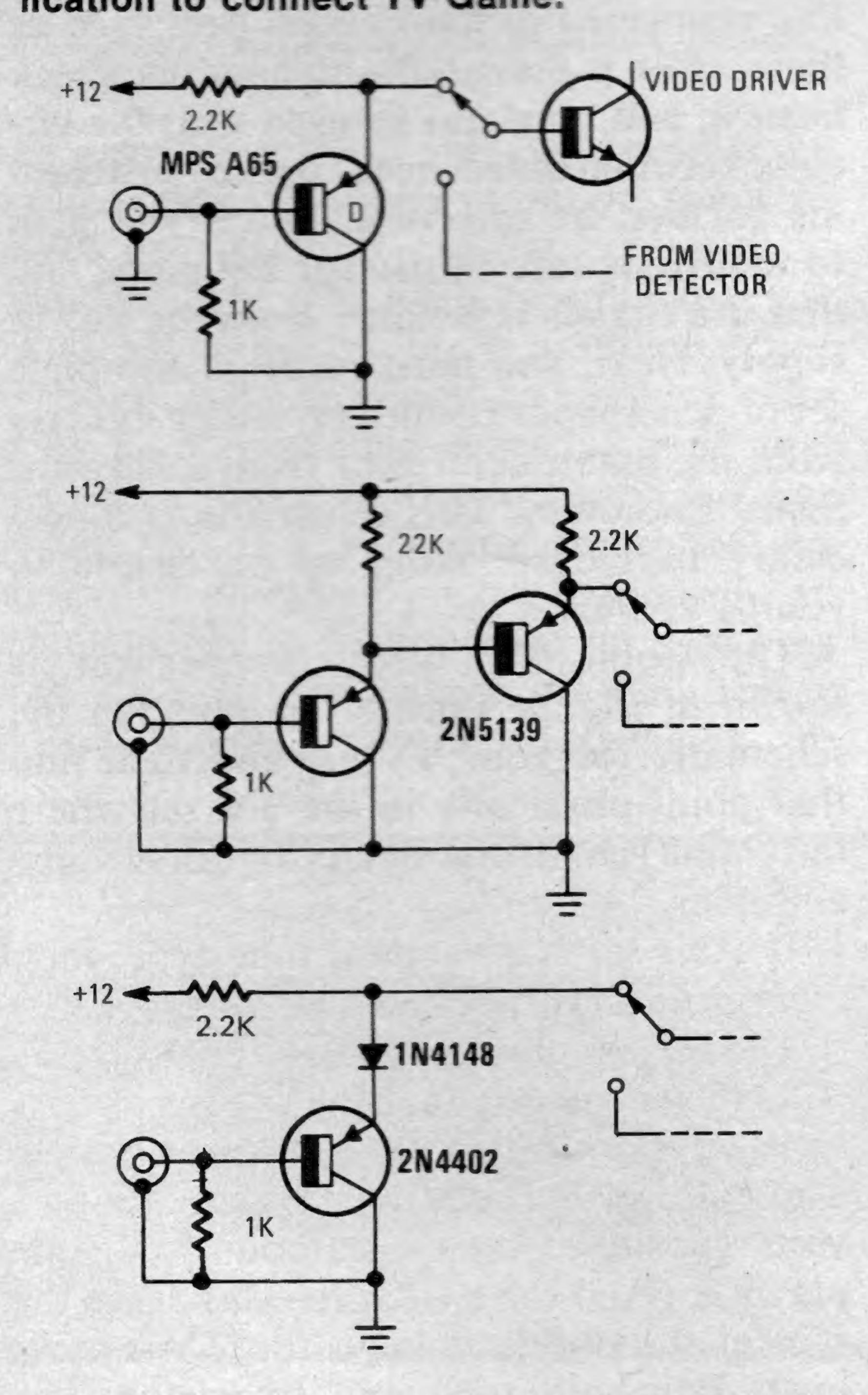
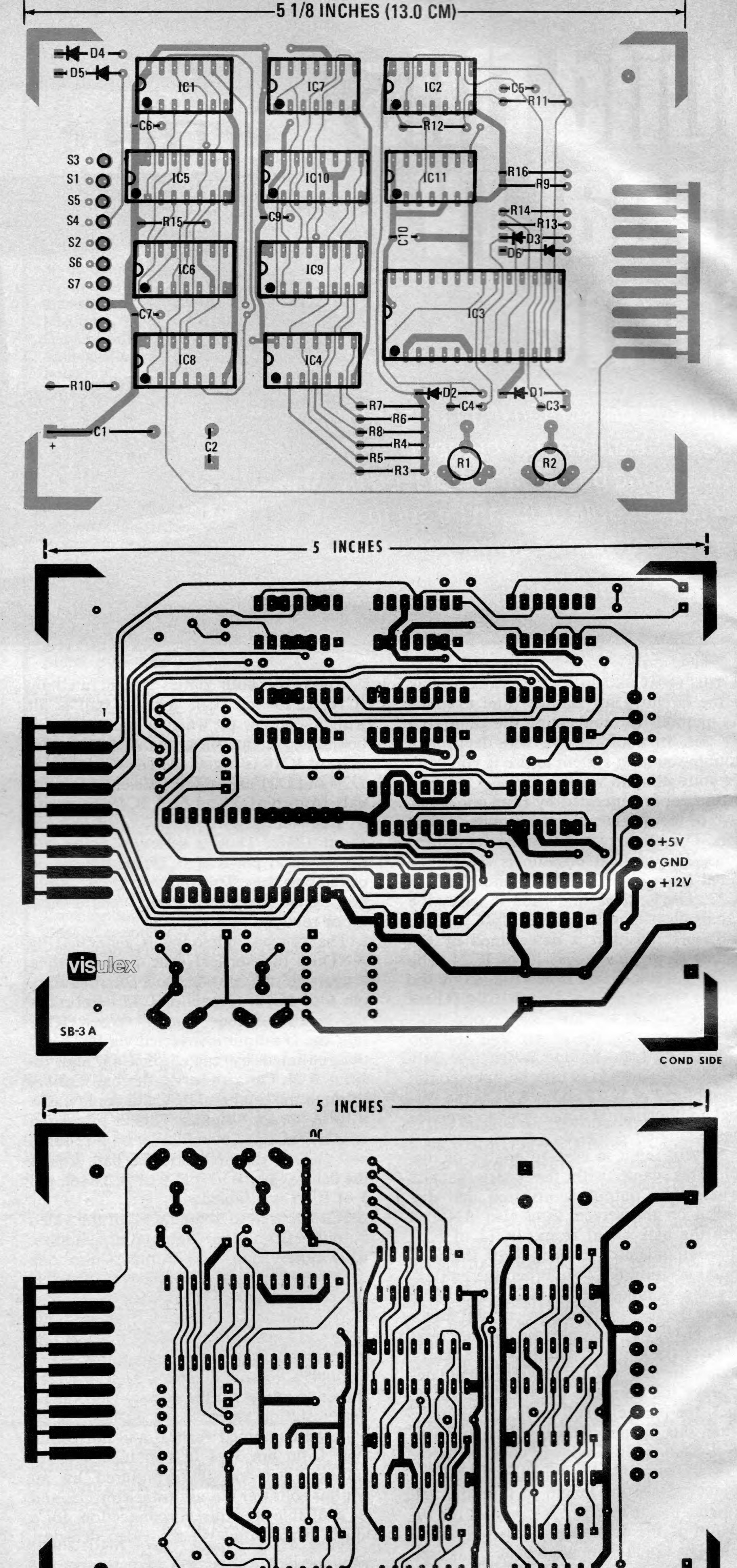


FIG. 3—TYPICAL CONNECTIONS to a transistor-type TV receiver.

The single-pole double-throw switch is designed to isolate the detector and normal bias network when the video input jack is used. Use leads as short as possible and make sure that if any lead run is



DIGITAL SCORING BOARD, component placement diagram (left, top). Foil pattern (left, middle) of component-side of double sided board. Foil pattern (left, bottom) of bottom-side of double sided board. Board measures 5 × 3½ inches.

PARTS LIST SCORING BOARD

All resistors 1/4-watt 5% unless noted

R1, R2-50,000 ohms, trimpot

R3, R4, R5, R6, R7, R8, R9, R13, R14, R16

-5100 ohms

R10-15 ohms

R11-510 ohms

R12-2000 ohms

R15-47,000 ohms

All capacitors 25 volts or more

 $C1-50 \mu F$, 25 volts

C2-1000 µF

C3-1000 pF

C4, C6, C7, C8, C9, C10-.05 µF

C5-270 pF

Diodes

D1 to D6-1N4148 or equal

Integrated Circuits

IC1, IC11-7400

IC2-74C00

IC3-5841 display IC provided with circuit board.

1C4 - 7406

1C5-75C04

IC6, IC7-74C90

1C8 - 7474

IC9, IC10-74153

Connectors

- 1 Ten-circuit male (Molex 09-64-1103 or
- 1 Ten-circuit female (Molex 09-52-3102)

longer than 3 inches, that you use shielded cable for these connections. (For additional information on direct TV connections, we recommend you refer to Don Lancaster's comprehensive article in the October 1975 issue of Byte magazine.)

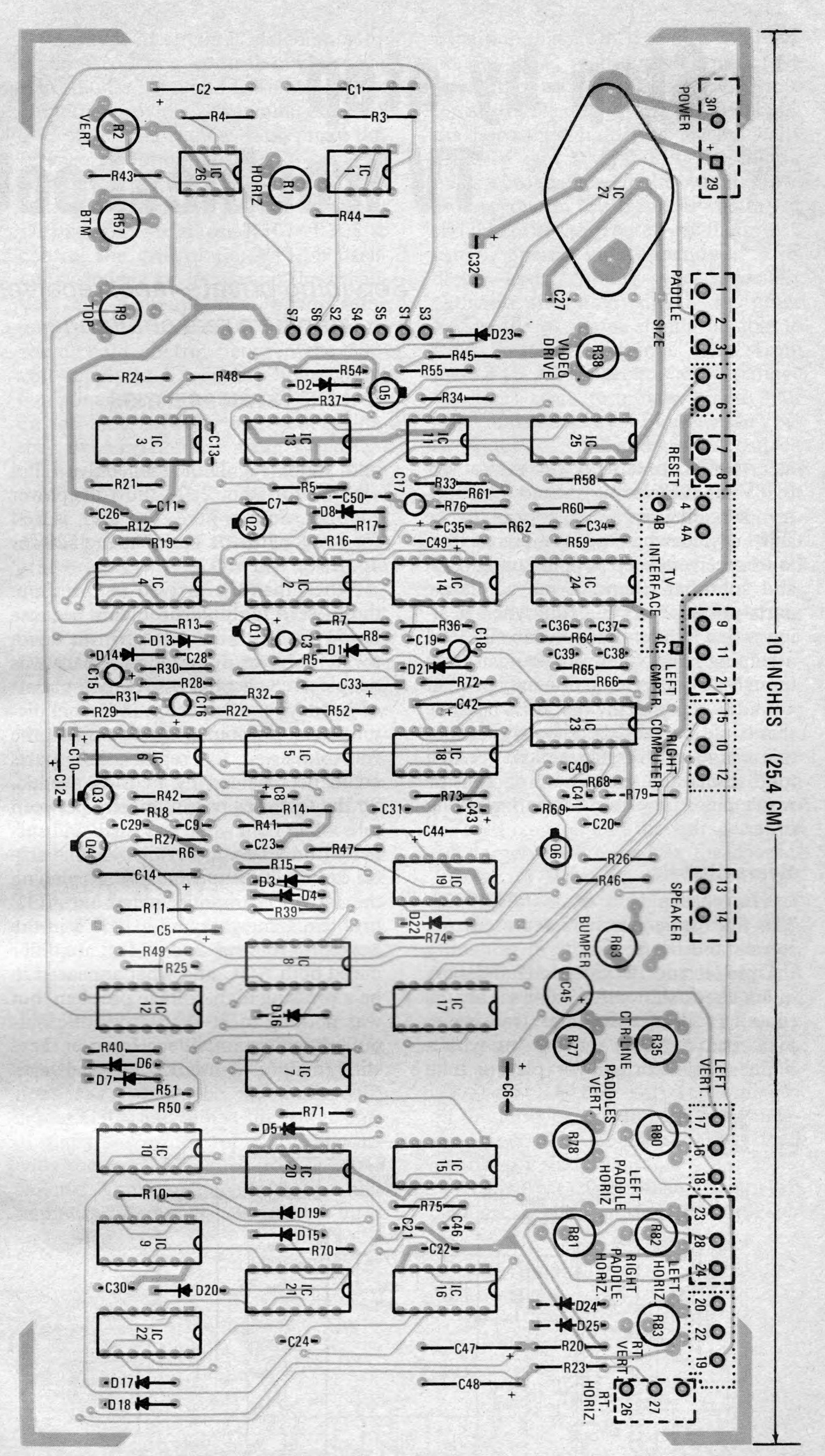
After you have completed the modification to the set, connect the game output, interconnect pads 4 and 4a to the video input jack with 2-wire 24-gauge lamp cord (Since the signal power is relatively low, unshielded wire will usually work. However, where even this potential interference is undesirable, use shielded wire). The lead on pad 4a should connect to the video jack ground terminal. Limit wire length to 15 feet.

When using this direct video connection, replace resistor R55 with a 10-µF capacitor (positive side goes to the emitter of Q6).

Operating instructions

Attach the unit's video output to the video input jack as just described in the previous section. Connect the power supply to 117 volts AC. Adjust the TV set's contrast control to maximum for deepest black. And lower the brightness control until the screen's raster is black. Only the paddles, ball, center line, and boundary should appear white.

Use the RESET button to put the game in the starting position with the score 0-0. If the game is shut down at a score of 18 and no ball can be seen, push the RESET button and release. The ball should reserve in about 2 seconds. If the ball is in motion, it will be necessary to allow the ball to go off-screen to either the right or



COMPONENT PLACEMENT DIAGRAM of main circuit board.

left and then to push and release the button before the ball re-serves.

When you want to play "BUMPER", use the GAME SELECT switch to select that game.

When automatic play is desired, flip one of the COMPUTER CONTROL switches to "on." In this mode, one person can play against the machine. When both switches are on, the machine will play against it-

In the manual mode, (computer con-

TROL switches off) use the player controller to control the horizontal and vertical position of the paddles. The game ends when the one player scores 18 points.

Trouble shooting

Most first-time or one-of-a-time projects of this size require some trouble shooting Ω and debugging. The best tools are a scope, comprehensive circuit description, schematic diagram, and a set of scope traces. continued on page 86 o